NREL's Integrating PV in Distributed Grids Workshop: Solutions and Technologies

A View from Hawaii

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Hawaiian Electric Company

Hawaiian Electric
Maui Electric
Hawai'i Electric Light

Our Vision

Cost-effective clean energy

- Achieve more than 65% Renewable Portfolio Standard (RPS) by 2030
- Meet Hawaii's goal of 100% RPS by 2045
- 20% bill reduction

Growing and equitable rooftop solar

- Accommodate growing rooftop solar
- Equitable for all customers

Modern grid

- Smart infrastructure
- Two-way flow of electricity and information
- Energy storage

Innovative energy solutions and services

- Community-based renewables, electrification of transportation, TOU, DR, microgrids, etc.

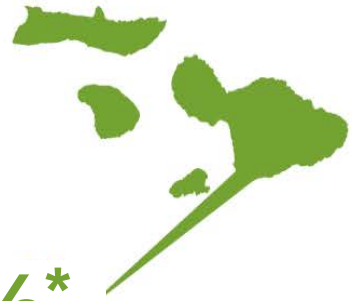
Hawaiian Electric: 3 Electric Utilities, 5 Separate Grids

Maui Electric
Serves islands of Maui, Molokai, and Lanai
Customers: 68,000
Generating capability: 284 MW
Peak Load (Maui): 190 MW

Hawaiian Electric
Serves island of Oahu
Customers: 297,000
Generating capability: 1,756 MW
Peak Load: 1,150 MW

Kaua'i Island Utility Cooperative **7.3%***

Hawaiian Electric **13.0%***



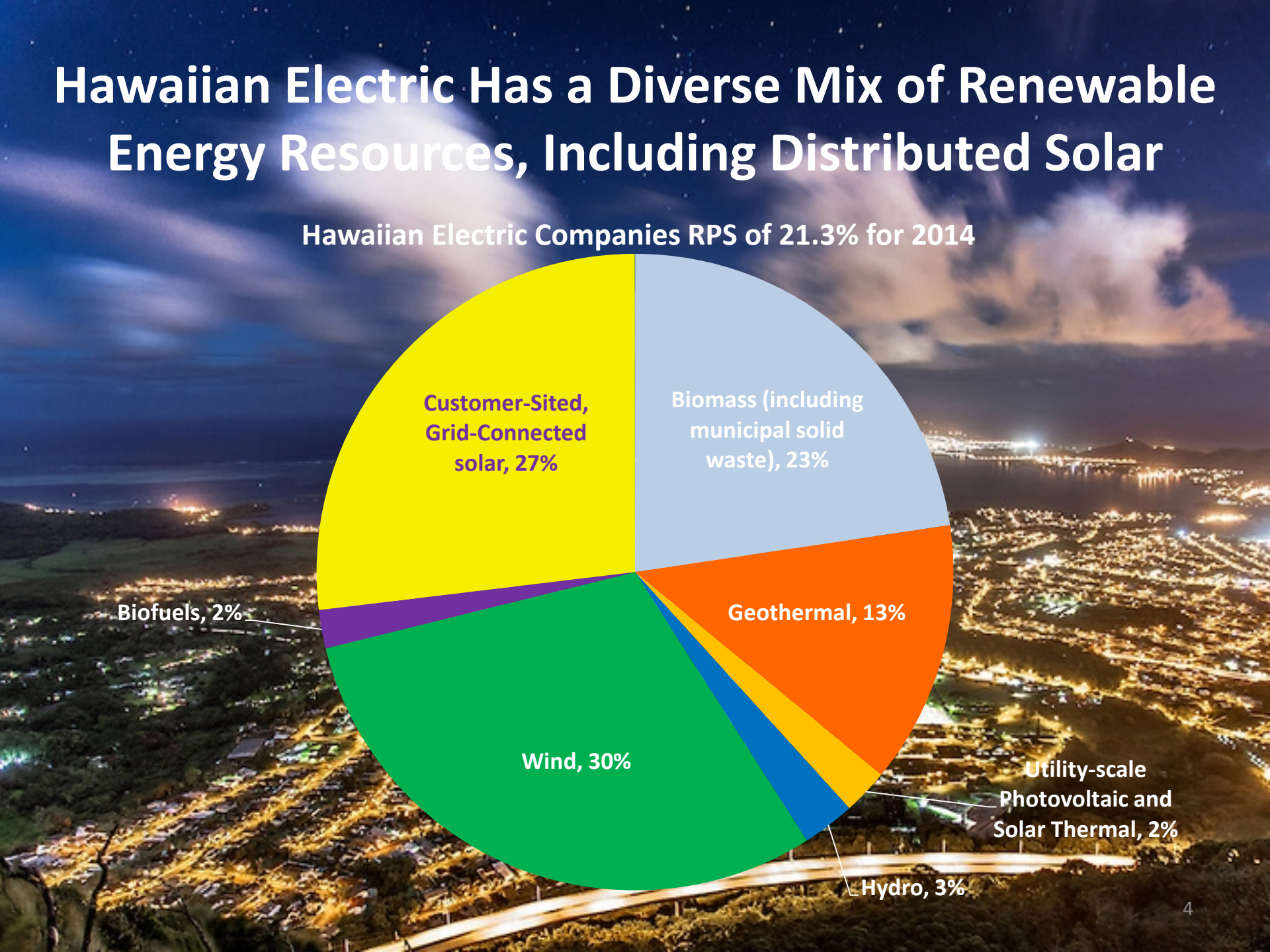
Maui Electric **12.0%***

Hawai'i Electric Light **10.0%***

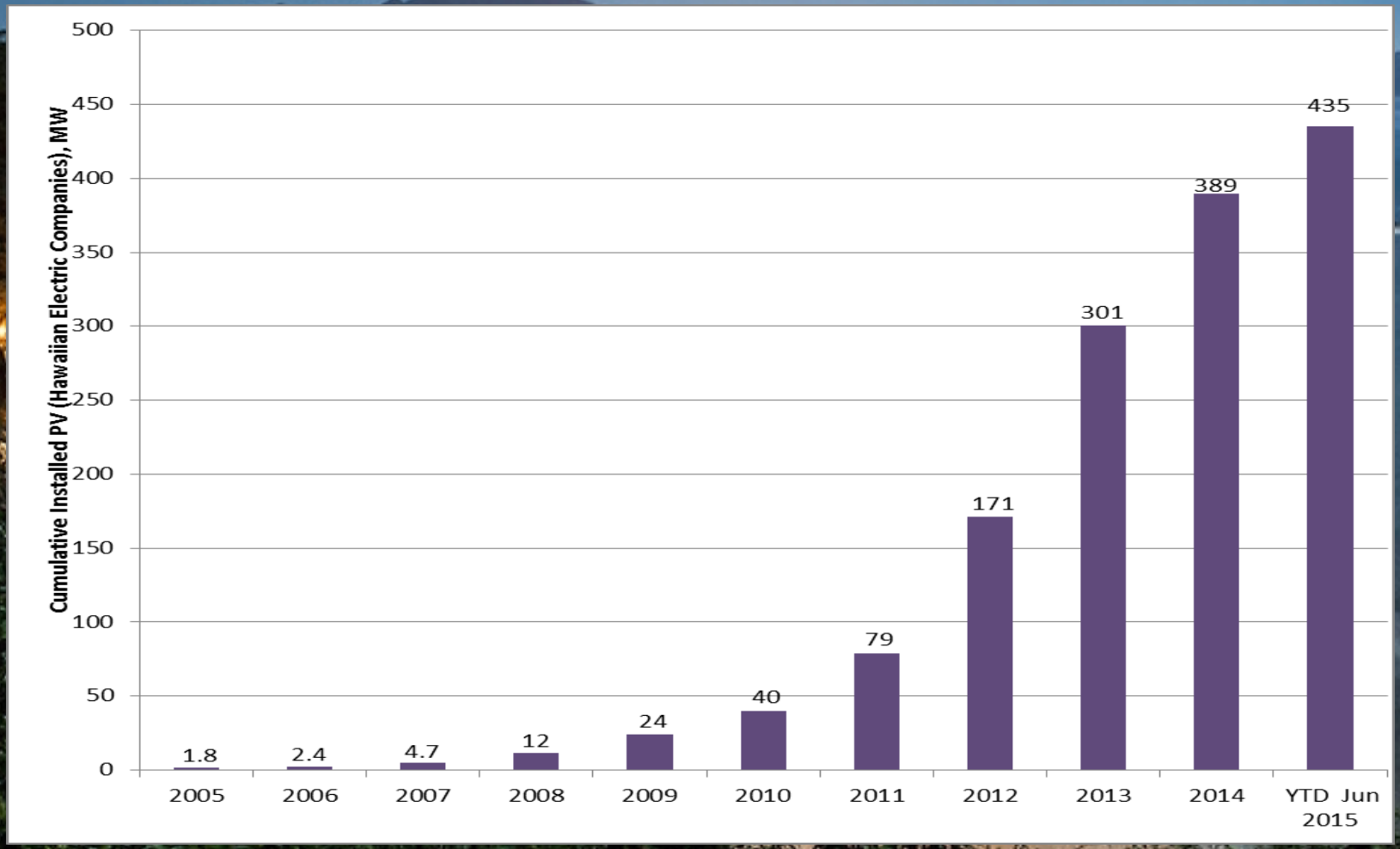
Percentage of Customers with PV
* As of 06/30/15
** As of 12/31/13
National data courtesy of Solar Electric Power Association

Hawaii Electric Light
Serves island of Hawaii
Customers: 81,000
Generating capability: 293 MW
Peak Load: 190 MW

Hawaiian Electric Has a Diverse Mix of Renewable Energy Resources, Including Distributed Solar



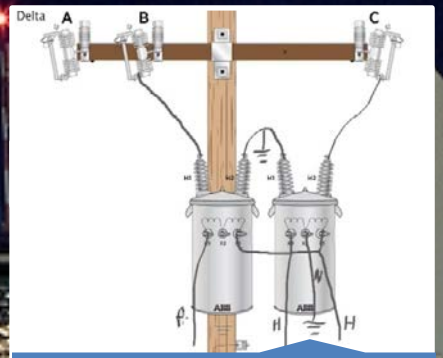
We Have Experienced an Exponential Growth in Photovoltaics on Our System



PV Systems and Inverters are Becoming a Growing Part of Our Distribution System

Distribution Wood Poles*

Company	Count
HECO	59,000
HELCO	52,000
MECO	30,000
Total	**141,000**



Distribution Transformers*

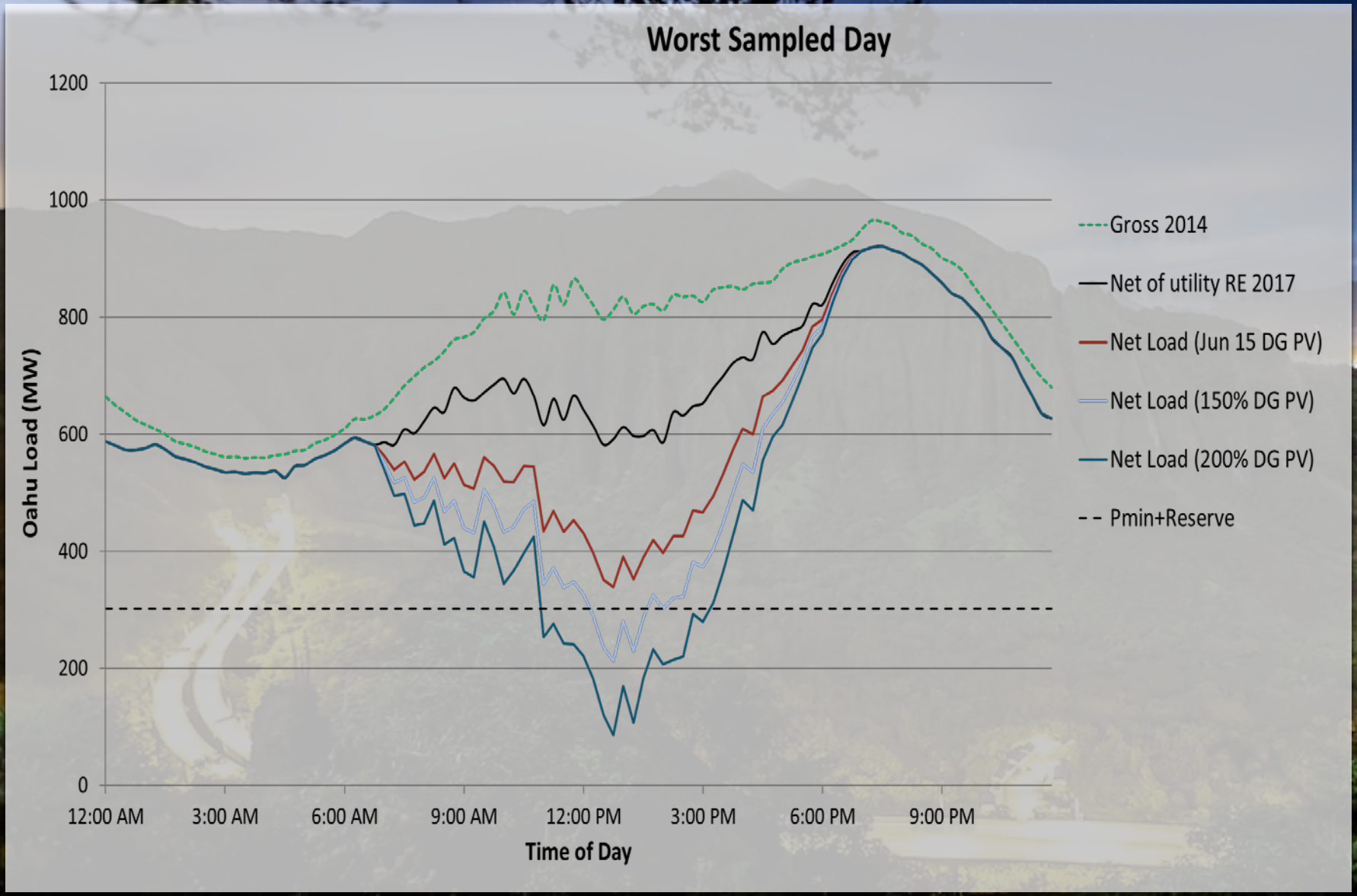
Company	Count
HECO	32,000
HELCO	24,000
MECO	12,000
Total	**68,000**

PV Systems*

Company	Count	kW
HECO	38,000	294,000
HELCO	8,000	61,000
MECO	8,000	63,000
Total	**54,000**	**418,000**

* Approximate numbers

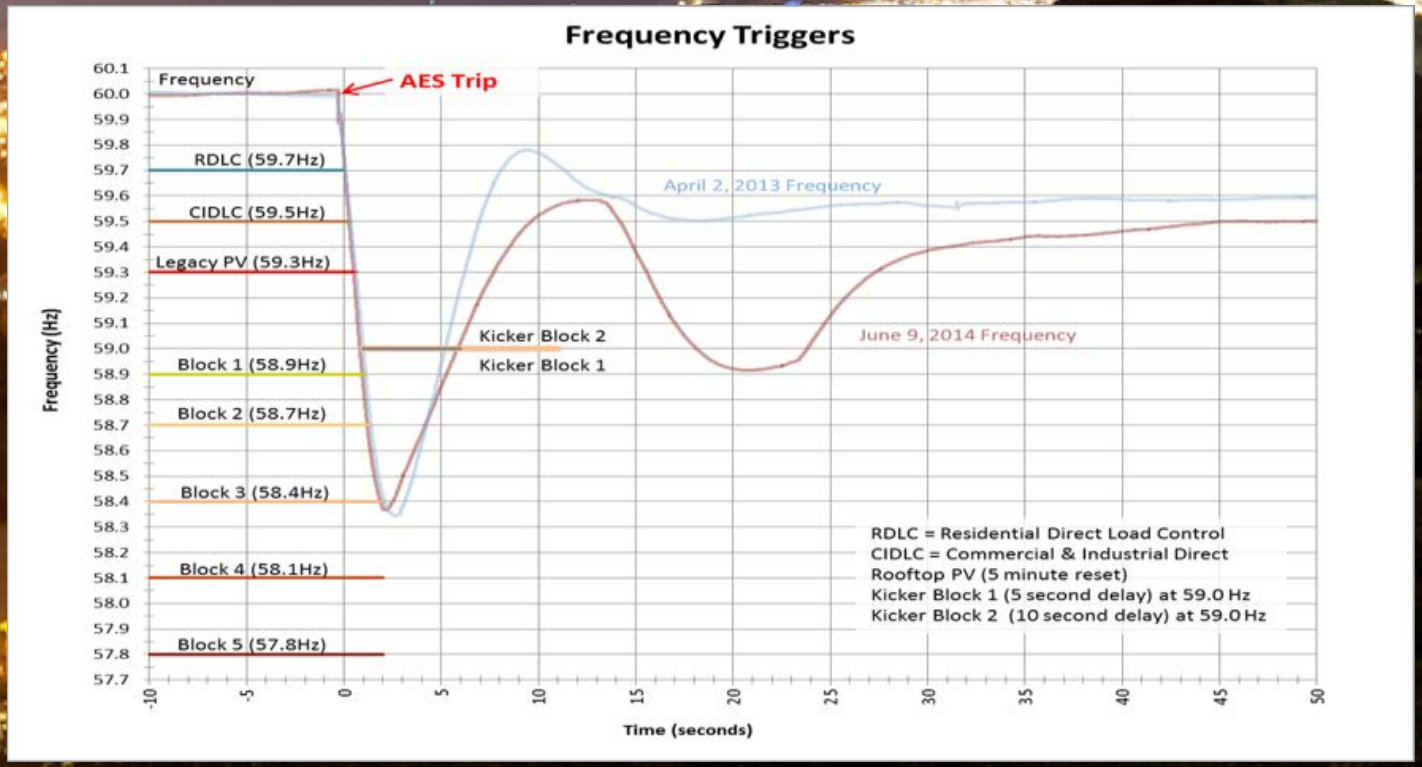
Variable Generation is Reducing Conventional



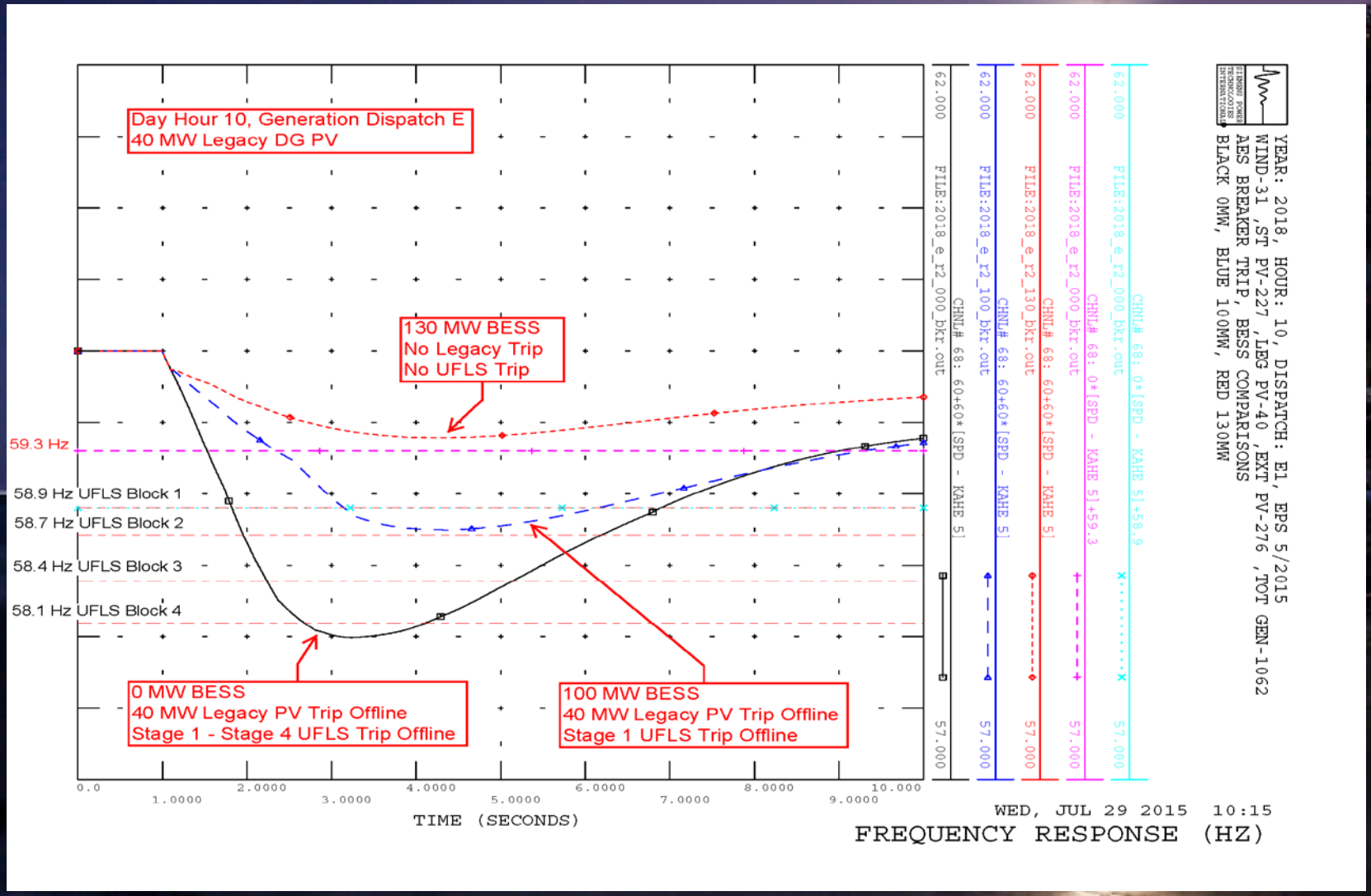
At The System Level, Reliability Levels are Lower Than in the Past

Today a large generator trip or system fault during peak PV periods results in:

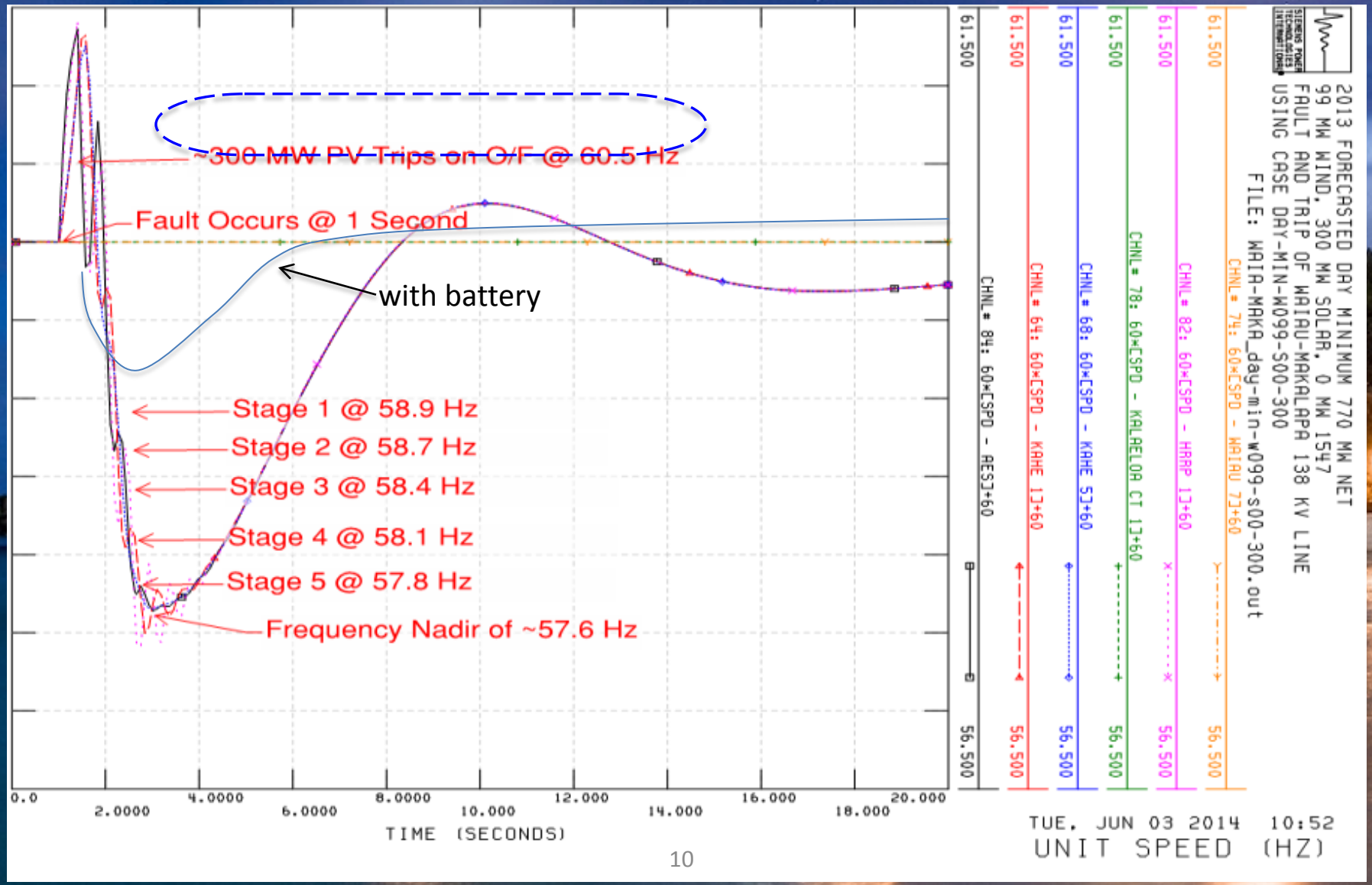
- Loss of system inertia due to reduction in rotating generation
- Loss of "legacy" PV which acts like a secondary generation loss
- Reduced effectiveness of UFLS due to rooftop PV
- Potential of massive load shedding (3-4 of 5 blocks of UFLS)
- Faster rate of change of frequency



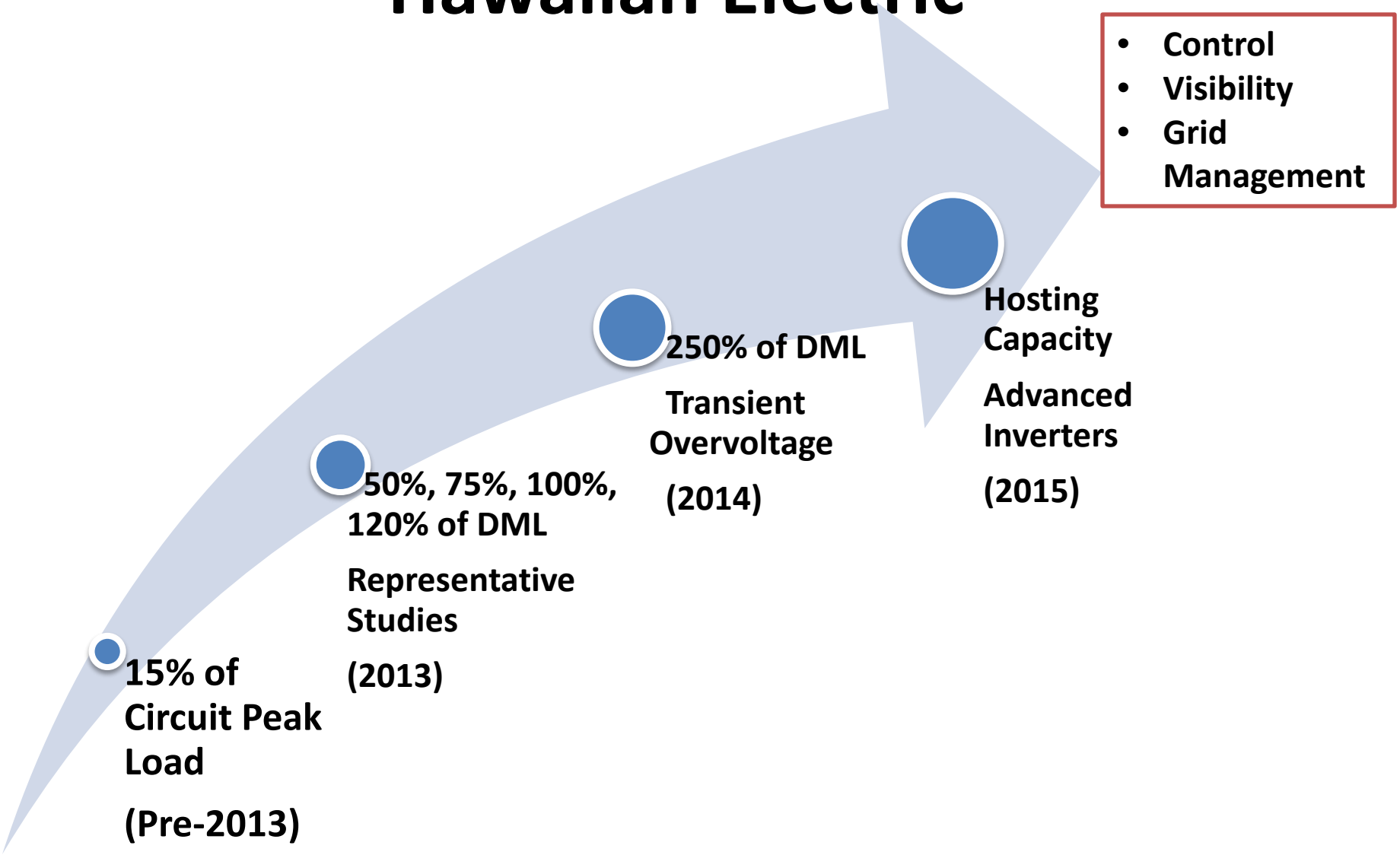
Battery Energy Storage System for Fast Frequency Response



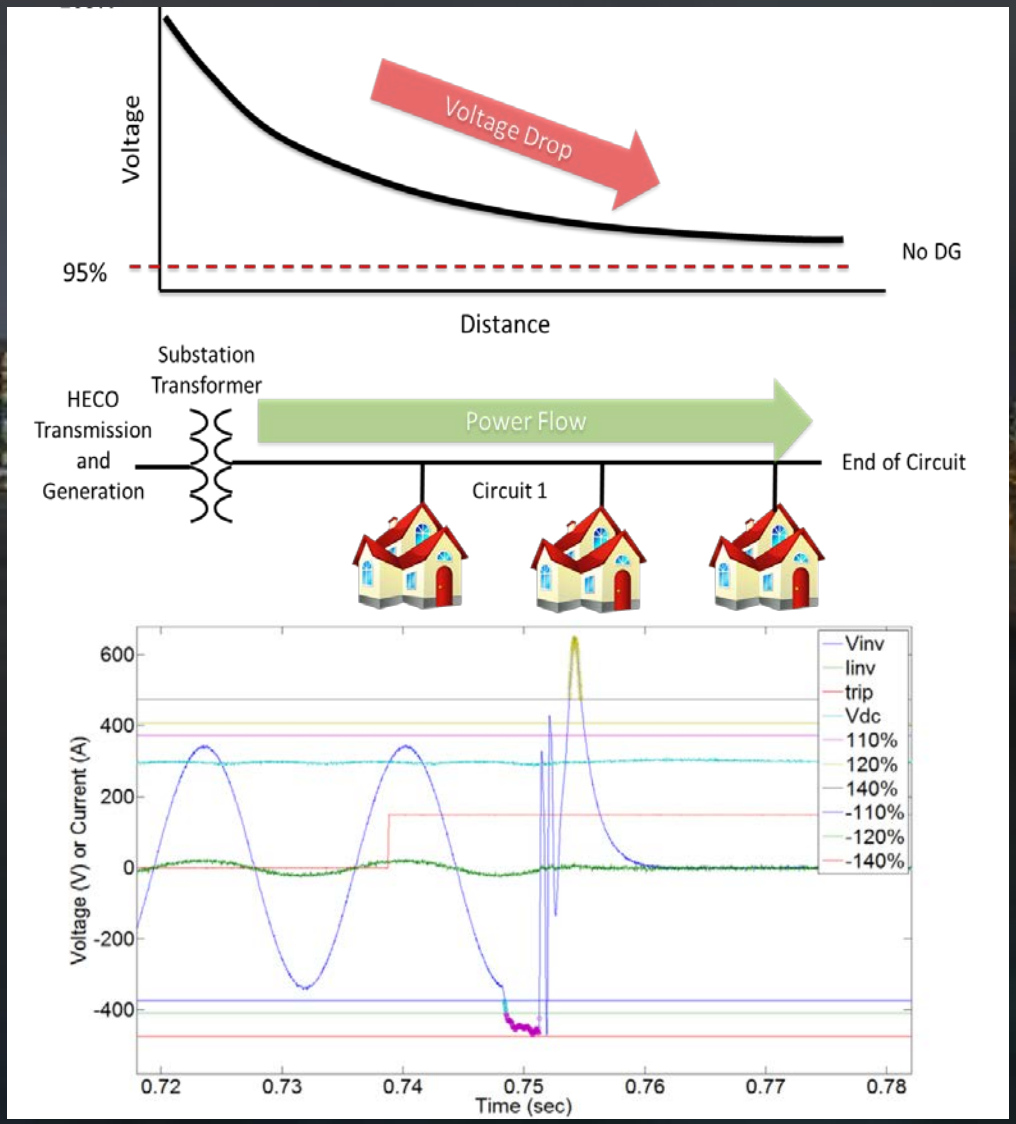
BESS Helps with Transmission Line Fault Event (Overfrequency)



Evolution of PV Integration for Hawaiian Electric



Hawai`i is Leading the Nation in Implementing Solutions for the Integration of Distributed Solar



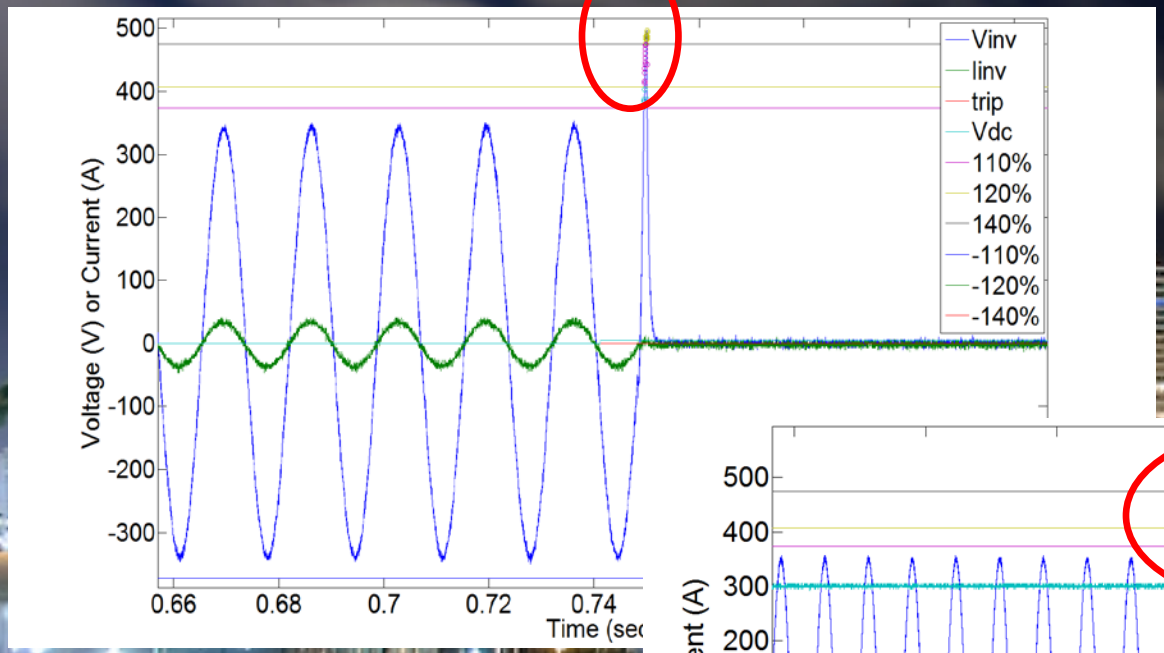
Distribution Level

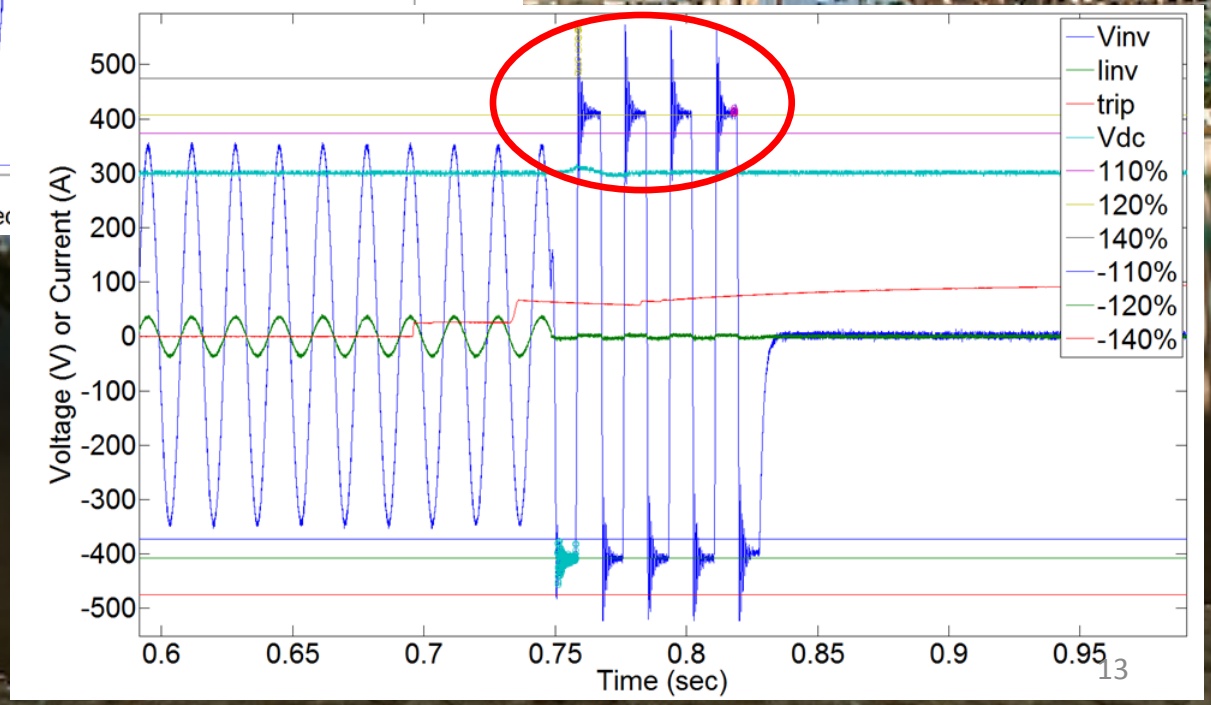
- Steady State
  - Thermal Capacity Over Load
  - Over Voltage issues
    - Primary
    - Secondary
    - Imbalance across phases
  - Protection
- Dynamic
  - Voltage Flicker
  - Voltage Regulation Impacts
  - Islanding
  - Load Rejection Over Voltage
  - Ground Fault Over Voltage

System Level

- Steady state
- Transient stability

Testing at NREL Provided an Opportunity to Perform Lab Tests in a Real World Environment

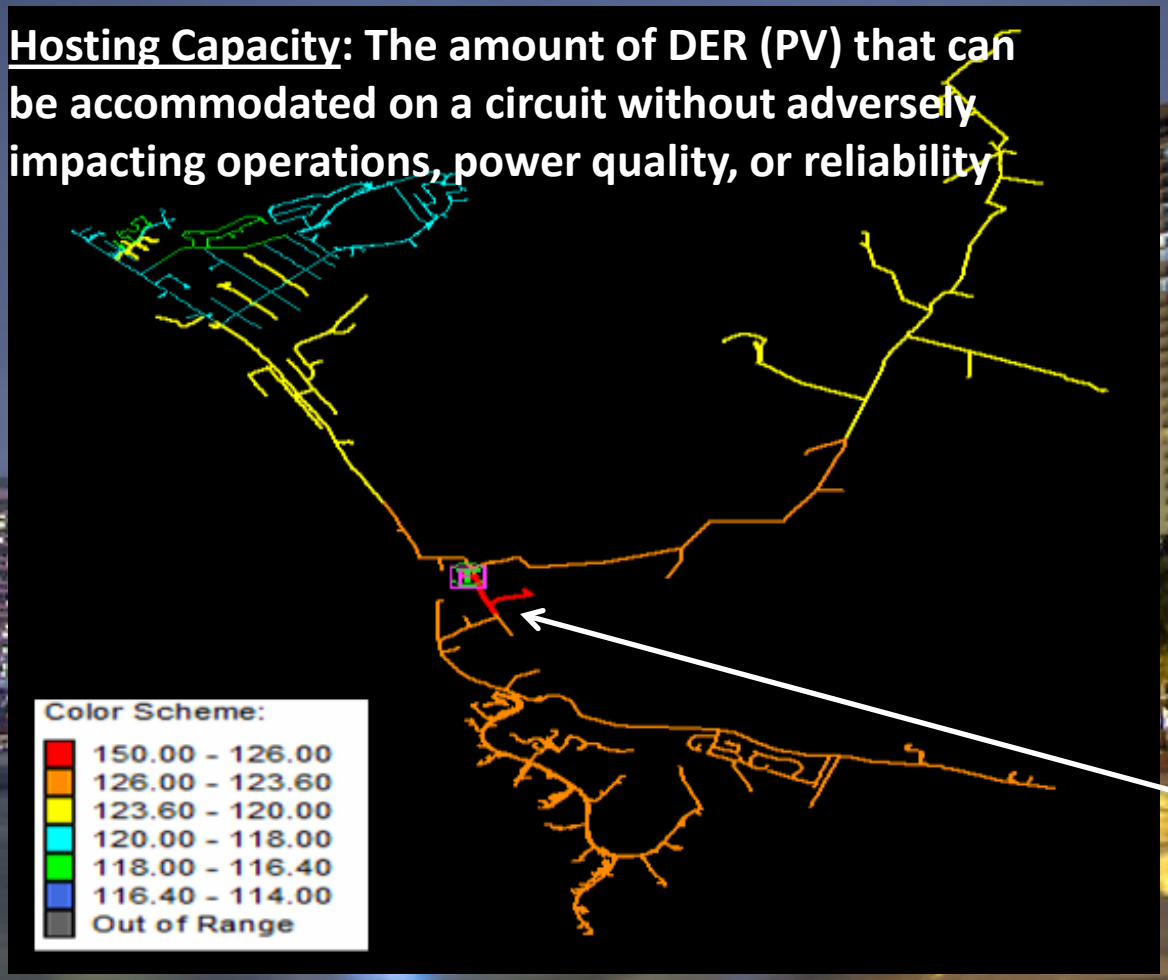




Energy Systems Integration Facility (ESIF)

At the Distribution Level, Circuit "Hosting Capacity" Method Used to Proactively Plan for and Integrate DER

Hosting Capacity: The amount of DER (PV) that can be accommodated on a circuit without adversely impacting operations, power quality, or reliability

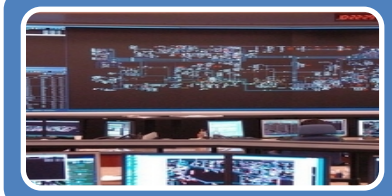


Heat Map Illustrative of Overvoltages Caused by High Amounts of Reverse Flow

We Are Working Through Rooftop PV Challenges

Cannot be Measured

- Rooftop PV output can only be estimated



Uncontrollable

- Cannot be turned on or curtailed

"Legacy" PV

- ~60 MW of PV generation trips offline at 59.3 Hz
- ~175 MW of PV generation trips offline at 60.5 Hz

Underfrequency Load Shed Schemes

- Decreases effectiveness of UFLS

Hawaiian Electric Company's Technical Plan

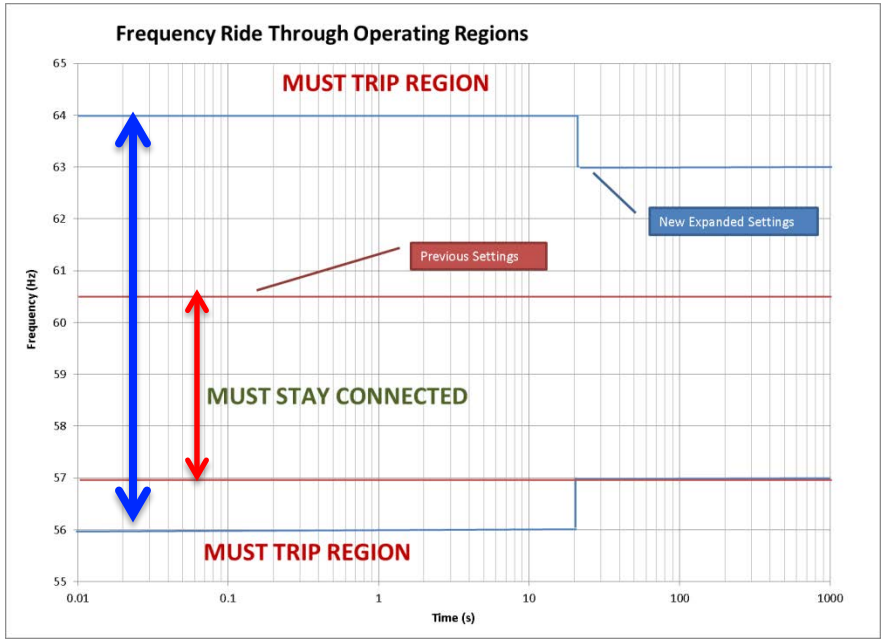
- System Level Limit
  System level screens for each unique island grid balancing system level reliability, safety, and cost-effective service to all customers

- Hosting Capacity
  Circuit level hosting capacities unique to each circuit to enable efficient interconnection process

- Advanced Inverters
  Early implementation and establishment of advanced inverter standards (fixed power factor, volt-watt, frequency-watt, communications, etc.) to cost-effectively and safely integrate distributed energy resources

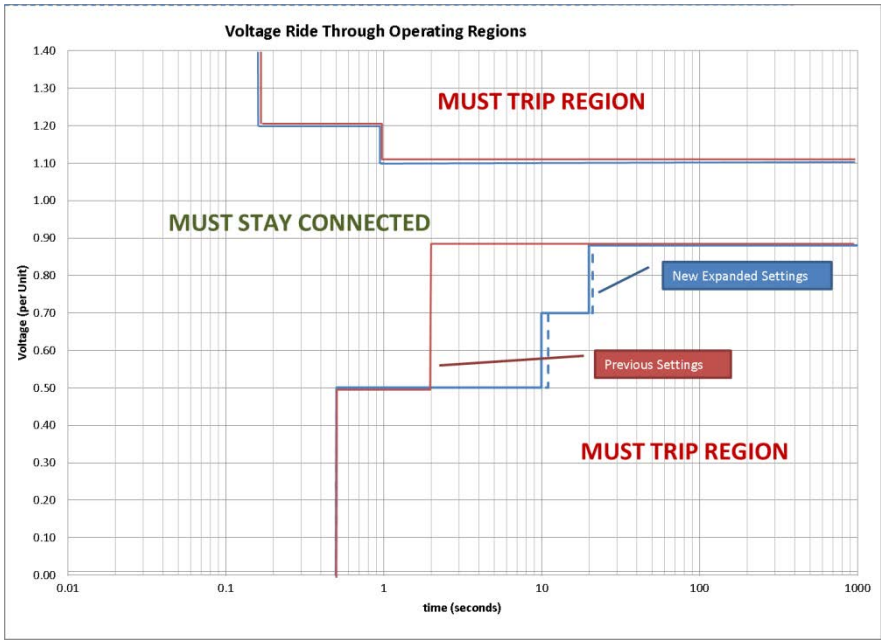
Ride-through Standards Were Established to Assist During System Disturbances

Low/High Frequency Ride-Through



Inverter will ride-through system contingencies (i.e. loss of large load or generating unit)

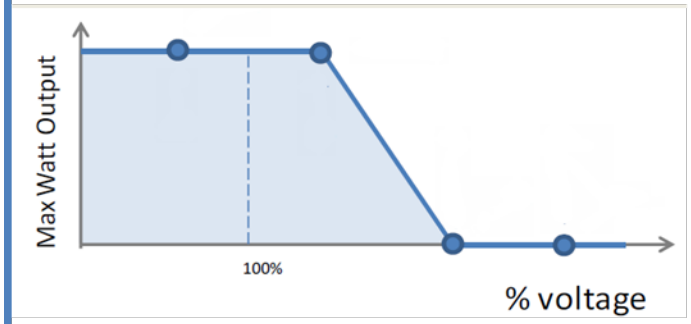
Low/High Voltage Ride-Through



Inverter will ride-through system or circuit disturbances (i.e. short circuit faults)

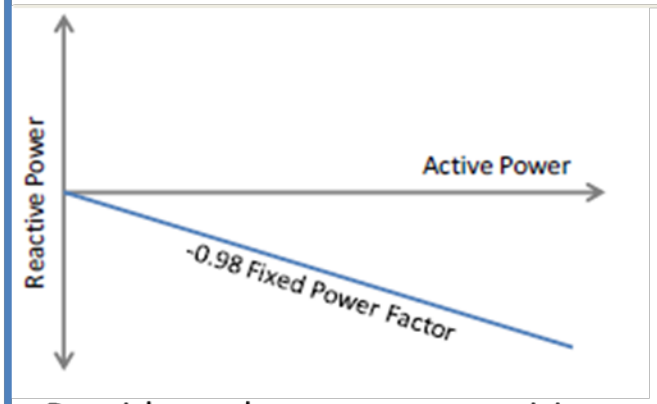
Adoption of Advanced Inverter Voltage Functions to Mitigate Voltage Issues

Volt-Watt



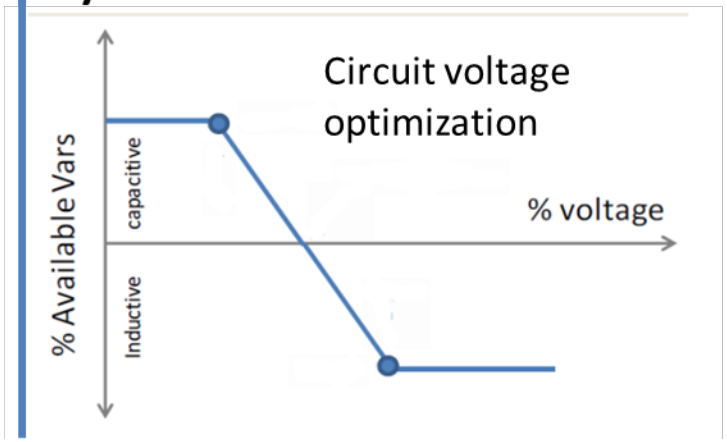
Mitigates secondary high voltage by reducing real power as a function of voltage.

Fixed Power Factor



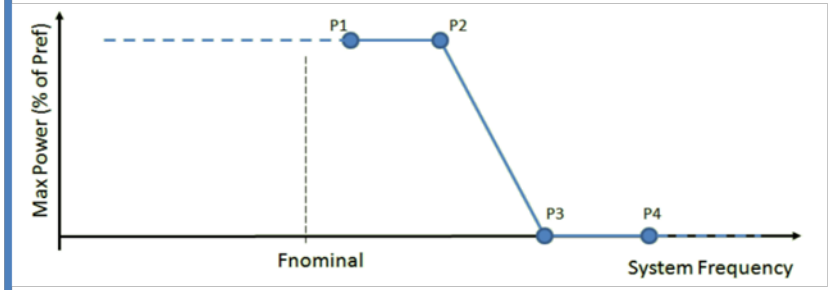
Provides voltage support; mitigate high voltages. May increase system losses.

Dynamic Volt-Var



Advanced Inverters for System Support

Frequency-Watt



May assist in over-frequency due to of loss of load/excess energy

Soft-Start

Gradually raises the inverter power output to coordinate with the ramping capabilities of the bulk generating system. Mitigates frequency swings during system restoration.

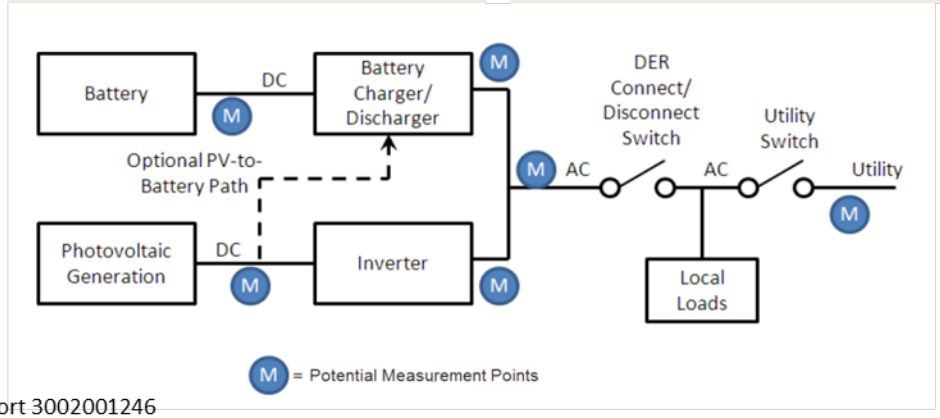
Remote Connect/Disconnect

Utility sends command to inverter to disconnect or reconnect system. To be used during system emergencies or system restoration.

Communications

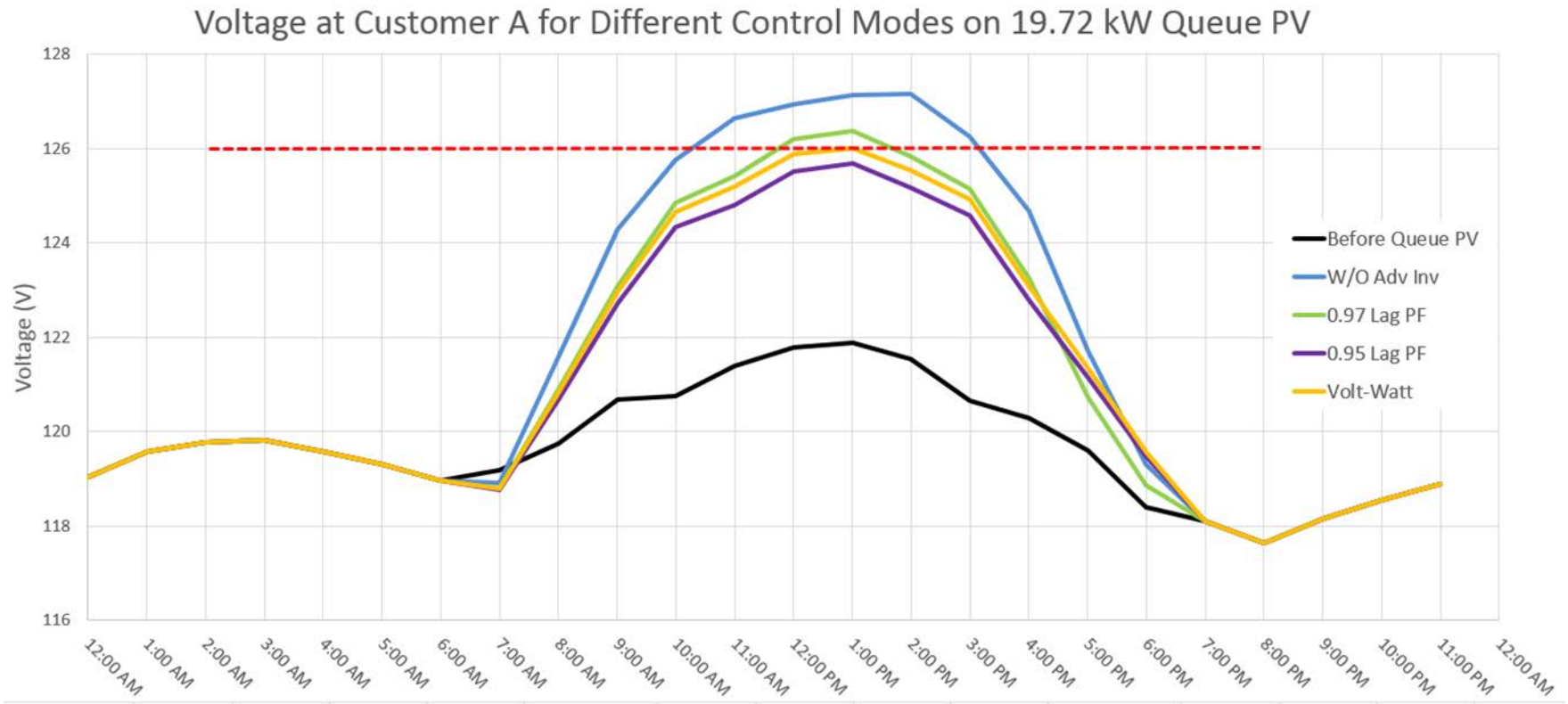
Remote Configurability

Measurement/Visibility

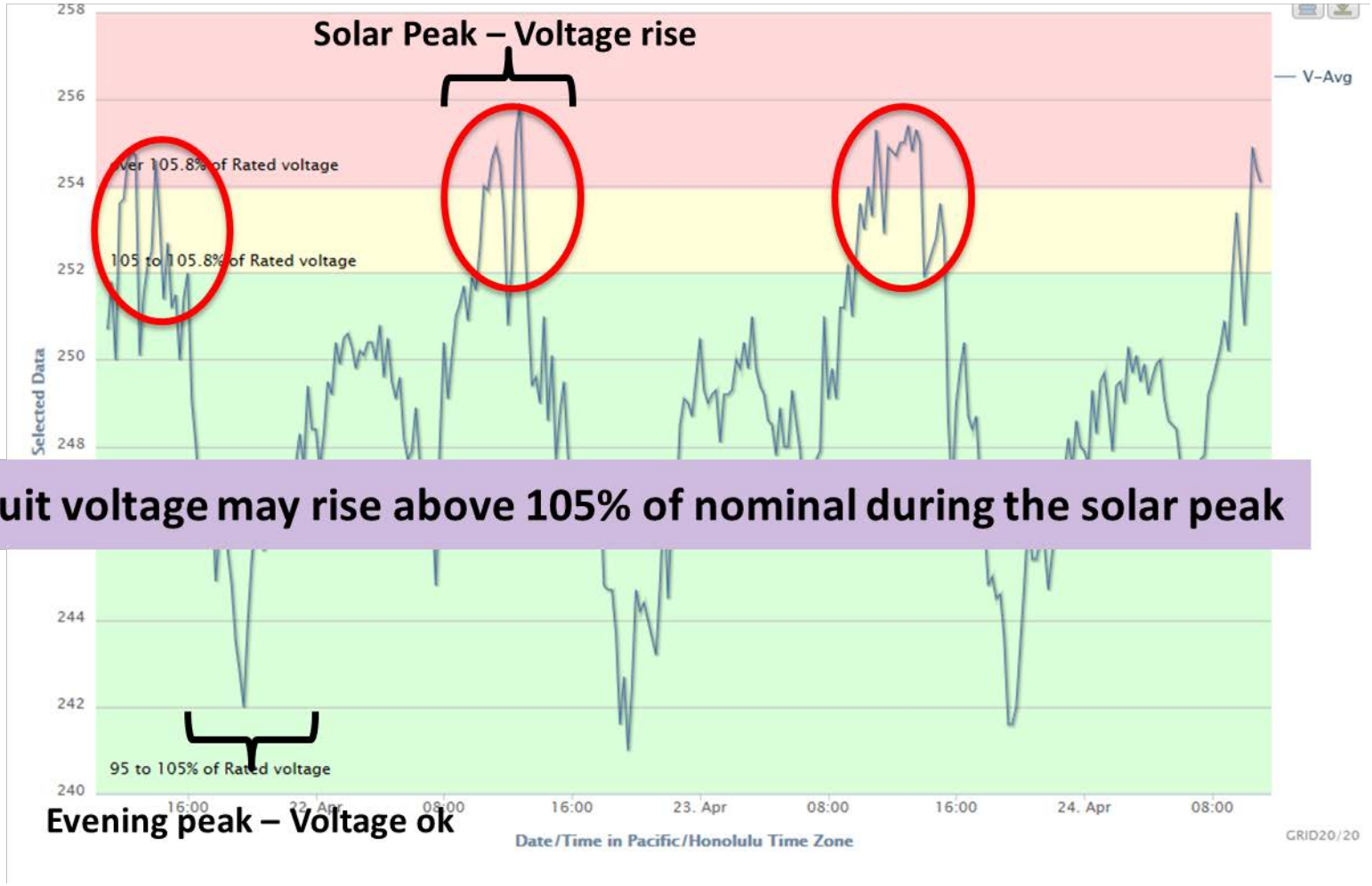


Source: EPRI Report 3002001246

Fixed Power Factor Can Mitigate Localized High Voltage and Reduce Voltage Fluctuations



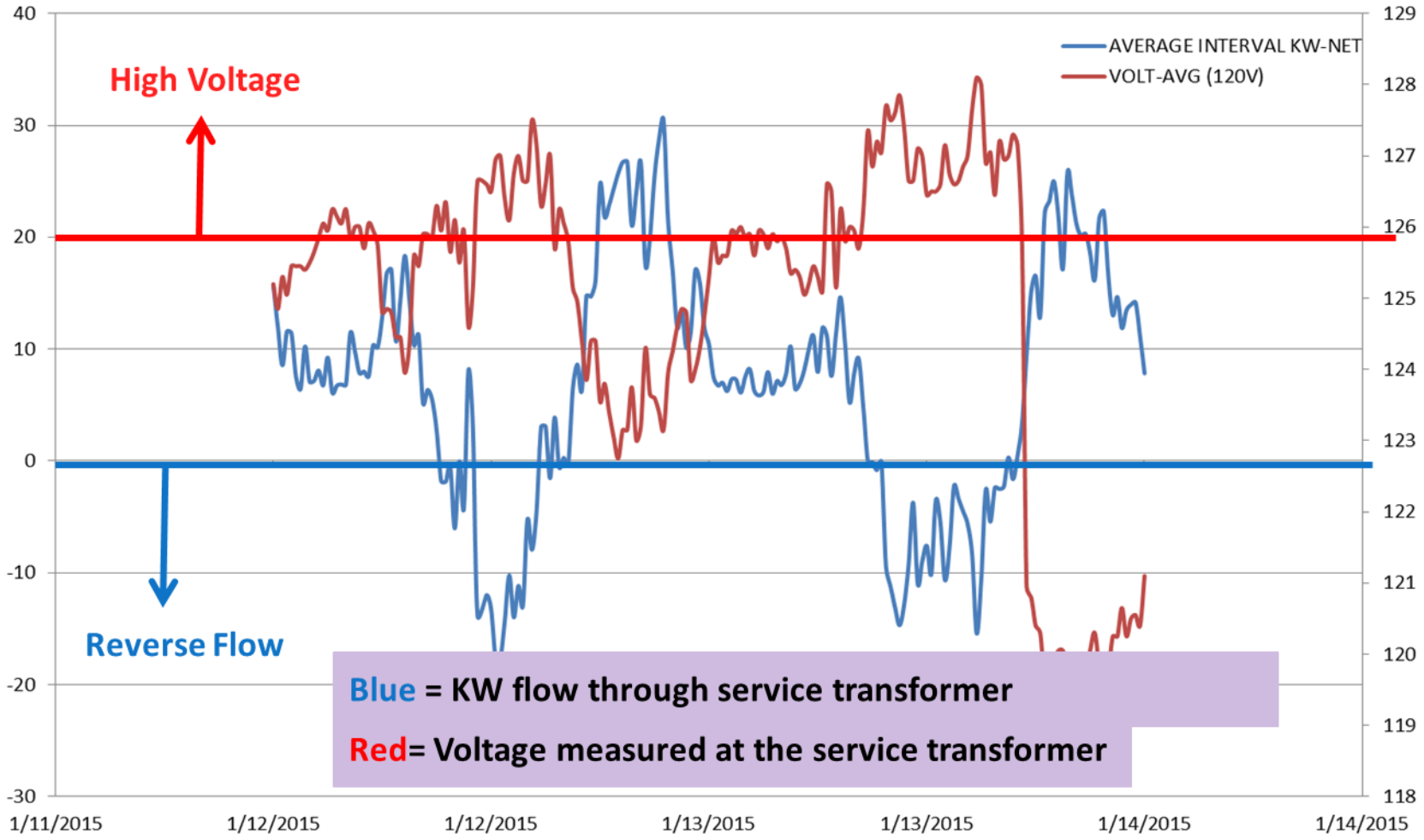
The Next Challenge: Real World Overvoltage Events Demonstrate that DER Systems Can Cause Overvoltage



Circuit voltage may rise above 105% of nominal during the solar peak

Evening peak – Voltage ok

Advanced Inverters Used to Manage Overvoltage Events



Lessons Learned

- Rooftop solar is a customer choice
- Consider DER as a grid asset – how do you extract the greatest value?
- It is an exercise in volume
- Get ahead of the curve

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